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PCT/EP 03/13295

21 APRIL 2004.

EP03/13295

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P01/7700 0.00-0227185.6

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MG/LD/P/21850.GB

2. Patent application number
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0227185.6

21 NOV 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

VOITH FABRICS HEIDENHEIM GmbH & CO. KG,
KURZE STRASSE 11,
89522 HEIDENHEIM,
GERMANY.

Patents ADP number *(if you know it)*

078411250C1

If the applicant is a corporate body, give the country/state of its incorporation

GERMANY

4. Title of the invention

NONWOVEN FABRIC

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

WILSON GUNN M'CAW
41-51 ROYAL EXCHANGE
CROSS STREET
MANCHESTER
M2 7BD

Patents ADP number *(if you know it)*

7153927001

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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11. I/We request the grant of a patent on the basis of this application.

Signature Wilson Gunn M'Caw Date 20.11.2002.

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NONWOVEN FABRIC

This invention relates to nonwoven fabrics and has particular, though not exclusive, relevance to nonwoven papermachine fabrics such as forming fabrics, press felts, dryer fabrics, through-air dryer (TAD) fabrics, hydroentanglement screens and transfer fabrics for use in a papermachine. The fabrics of the invention also have application as transfer/conveyor fabrics in machines other than papermachines and may be used, for example, as conveying fabrics, or as screens for latex impregnation of conventionally air-laid materials, for screens used in melt blowing processes or for screens used in spun bonding.

Paper is conventionally manufactured by conveying a paper furnish, usually consisting of an initial slurry of cellulosic fibres, on a forming fabric or between two forming fabrics in a forming section, the nascent sheet then being passed through a pressing section and ultimately through a drying section of a papermaking machine. In the case of standard tissue paper machines, the paper web is transferred from the press fabric to a Yankee dryer cylinder and then creped, or alternatively on more modern machines a monofilament woven mesh dryer fabric conveys the web from the forming fabric to a through-air dryer, followed by a Yankee cylinder.

Papermachine clothing is essentially employed to carry the paper web through these various stages of the papermaking machine and to facilitate water removal from the sheet in a controlled manner. In the forming section the fibrous furnish is wet-laid onto a moving forming wire and water is encouraged to drain from it by means of suction boxes and foils. The paper web is then transferred to a press fabric that conveys it through the pressing section, where it is usually

passes through a series of pressure nips formed by rotating cylindrical press rolls. Water is squeezed from the paper web and into the press fabric as the web and fabric pass through the nip together. In the final stage, the paper web is transferred either to a Yankee dryer, in the case of tissue paper manufacture, or to a set of dryer cylinders upon which, aided by the clamping action of the dryer fabric, the majority of the remaining water is evaporated.

Papermachine fabrics traditionally consist of a woven fabric. As the warp and weft yarns interweave, a so-called "knuckle" is formed as they cross. These knuckles have a tendency to mark the paper sheet formed on the fabric. This problem is particularly apparent at the wet end of the papermachine where the sheet is still highly plastic. In recent years, various methods have been suggested for making nonwoven papermachine fabrics in order to eradicate the problem associated with knuckle marking, particularly for press and dryer section applications. Many of these have been impractical to manufacture commercially.

GB 1,053,954 describes a nonwoven papermakers' fabric comprising two layers of parallel polymeric filaments, the layers being attached together in such a manner that the filaments of one layer are disposed at an angle with respect to the filaments in another layer. Such an arrangement is not durable and consequently this fabric is not commercially viable.

US 3,617,442 describes a forming fabric comprising a sheet of synthetic, open-celled, flexible foam such as polyurethane. This is reinforced by a series of polyester cables, a coarse wire screen or a thin flexible metal or plastic sheet. Such an arrangement, if ever commercialised, would exhibit poor wear resistance.

GB 2,051,154 relates to a so-called "link belt" in which a base fabric is formed from a series of interdigitated helices joined together by pintle wires. Link belts are only suitable for certain applications, due to calliper and material restrictions.

US 4,541,895 describes a papermakers' fabric made up of a plurality of nonwoven sheets laminated together to define a fabric or belt. The nonwoven sheets are perforated by laser drilling. Such sheets are composed of unoriented polymer material, and if produced in the fineness needed for papermaking applications, would lack sufficient dimensional stability to operate as endless belts on papermachines.

The subject invention of GB 2,235,705 describes a base fabric for press felts. Here an array of sheath core yarns of which the core has a higher melting point than the sheath, is fed in spaced parallel disposition to peripheral grooves of a pressed roller arranged in nip-forming relationship with a press roll. The material of the sheath is melted as the yarns move into and through the roller nip and excess melted sheath material is forced into lateral and vacant circumferential grooves in the roller to form structural members between adjacent yarns. A wide belt may be formed by joining similar strips together. A batt of fibres is subsequently needled to the base fabric so as to form a press felt. The base fabric provided in accordance with GB 2,235,705 has large land areas. Thus there is a lot of "dead" space which can result in the production of an uneven paper sheet. Also perforations through the mesh-like base fabric extend straight through the fabric. This is undesirable for paper sheet formation, where controlled dewatering is required, especially during the delicate sheet forming phase.

GB 2,241,915 relates to a method of producing a papermaking fabric in which a layer of photopolymeric resin is applied to a moving band. A moving, selectively transparent, mask is positioned above the resin and the resin is irradiated through the mask to effect an at least partial cure of the parts of the resin layer in register with the transparent regions of the mask. After irradiation uncured regions of the resin are removed by pressure fluid jets and final curing of the resin is effected either thermally or by means of flooding actinic radiation. The foraminous sheet so formed may be reinforced with yarns or fibres. Once again holes extend straight through the fabric. This is undesirable for paper sheet formation and additionally permits the occurrence of harmful "backwash" which comes from hydraulic pulses passing through the fabric from the machine side. The direct passage of these pulses disturbs the fragile cellulosic fibrous network.

GB 2,283,991 relates to papermachine clothing made from partially fused particles. A reinforcing structure is embedded within the structure. This papermachine clothing is suitable for pressing applications and possibly special forming applications.

US 5,501,824 describes an apparatus and method of making three-dimensional objects out of a modified wax, which becomes fluid on heating. The solid wax object may easily be damaged. The method would have particular application in the production of small prototypes, which are then generally embedded in foundry moulding sand to enable a metal casting to be made. The prototypes are formed, on a vertically moveable platform, by disposing the material in a controlled manner from a nozzle. The nozzle and platform are moveable under the control of a computer such that the material dispensed from

the nozzle is in the correct location to build up the prototype in the manner illustrated in a CAD system connected to the computer. Support material for the desired object is constructed first during the method, where required, and is later removed.

The products made in accordance with US 5,501,824 and other stereolithographic methods have been one-off prototypes which are generally rigid and have no function other than to aid the manufacture of an end product of similar dimensions, but which is made from a different material, for example metal.

The use of stereolithographic technology in the manufacture of papermachine clothing and other industrial fabrics has not previously been contemplated in that the potential of applying that technology to flat, wide, long flexible structures has not hitherto been considered.

According to a first aspect of the present invention there is provided a method of making a fabric by stereolithography.

For the avoidance of doubt the term "stereolithography" as used herein embraces, amongst other techniques, so-called selective deposition modelling. An example of selective deposition modelling is found in US 5,501,824. The fabrics in accordance with the invention have particular, although not exclusive application in the manufacture of papermachine clothing. This technology has been identified as being ideally suitable for the manufacture of forming fabrics.

The term stereolithography used herein describes the formation of a three-dimensional object, tomographically layer by layer, in a stepwise fashion out of a material capable of physical transformation. This may be achieved in a number of

ways. In one approach (selective deposition modelling) layers of fluid material are laid down stepwise in the desired locations and are each solidified as they are laid down. Alternatively, but less preferably, a layer of liquid or sinterable material is laid down and only the required areas for forming the structure are solidified, or fused together, as appropriate, by the accurate application of incident radiation.

According to a second aspect of the present invention there is provided a method of making a fabric from a material comprising the following steps:- feeding material from at least one nozzle onto a moveable belt, wherein said nozzle is moveable for translational movement and the spacing between said nozzle and the belt is adjustable, and wherein flow through said nozzle and translational movement of said nozzle is controlled such that said nozzle dispenses the material in a controlled manner to form the fabric layer-by-layer.

The nozzles are ideally provided in at least one feed head, a number of nozzles being provided in each feed head. A plurality of feed heads would conventionally be used.

The method facilitates the manufacture of a wide variety of fabric configurations. A wide variety of foraminous fabrics may be made having any aperture size, shape and distribution. The aperture size, shape and/or distribution may be deliberately varied, within desirable tolerances, throughout (or at least in the paper support surface of) the fabric although the porosity of the fabric should be kept as uniform as possible. By varying the size, shape and distribution of the apertures in the paper support surface of the fabric the undesirable periodicity associated with regular weave structures is avoided.

The fabric filaments which are built up during the process may be of any cross-section, eg round, square or triangular.

The fabrics of the invention ideally comprise an array of yarns extending in the intended running direction thereof, such fabrics being generally used as belting. These yarns provide strength in the machine direction. The yarns are preferably monofilaments or multifilaments and are ideally made from any of the following materials: steel, polyester, polyamide, polyolefin, PPS, PEEK, para-aramid or from inorganic material, for example glass or basalt. The yarns are preferably at least partly, and ideally fully, encapsulated in the machine direction lands of the nonwoven fabric.

Ideally the aforesaid material for making the fabric is normally (at room temperature (20°C)) in a solid state and preferably is made molten by heating. In such circumstances the droplets of material cool and thus solidify as they are deposited. Alternatively a fluid material which may be cured by the application of incident radiation, such as actinic radiation or electron beam radiation, may be used. In such circumstances ultra-violet curable resins are preferred, the radiation being applied as the material is laid in place.

The preferred material for making the fabric comprises a low viscosity (80-300 Centipoise measured at room temperature (20 °C.)) hot melt polymeric material.

One possible alternative stereolithographic approach to manufacturing by selective deposition modelling as described above utilises the selective curing of a layer of polymeric material which is fed onto a moveable belt by one or more dispensing heads. The desired regions of the polymer layer may be cured by the

incident radiation. In a particularly preferred embodiment the polymer is a liquid photopolymer which is cured by ultra-violet radiation. A laser is used to apply the radiation so as to facilitate precise curing of the desired regions of the polymer layer. The non-cured material drains away leaving a layer of cured polymer material of the required configuration of the fabric.

In a further alternative method sinterable powdered material is fed onto a moveable belt by one or more dispensing heads. The desired regions of the sinterable material are then fused together by incident radiation, preferably from a laser.

The method of the invention may be used to form complicated fabric structures, with filaments of end sections, which cannot be utilised in conventional weaving. For example the fabric may comprise lands, filaments or strands which are triangular in cross-section. Yarns with such end sections would be liable to twisting or distortion during insertion into a woven fabric on a loom.

In one embodiment apertures are provided in the support surface having dimensions which would accord to those of current woven fabrics. However, fabrics having smaller apertures may be made in accordance with the method of the invention. Typically the notional diameter of the apertures would be in the range from 100 μm to 800 μm.

In order that the present invention may be more readily understood specific embodiments thereof will now be described by way of example only with reference to the accompanying drawings in which:-

Fig. 1 is a diagram of one apparatus for making a nonwoven fabric in accordance with the present invention;

Fig. 2 is a perspective view of part of one nonwoven fabric made in accordance with the present invention;

Fig. 3 is a side elevation of the nonwoven fabric of Fig. 2;

Fig. 4 is a diagrammatic illustration of the underside of the nonwoven fabric of Figs. 2 and 3 shown during various stages of construction;

Fig. 5 (including Figs. 5a and 5b) shows alternative methods of producing a fabric in accordance with the invention from a series of panels extending in the cross-machine direction each made using the apparatus of Fig. 1;

Fig. 6 shows a method of producing a fabric in accordance with the invention from a series of panels extending in the machine direction each made using the apparatus of Fig. 1;

Fig. 7 is a perspective view of a second nonwoven fabric made in accordance with the present invention;

Fig. 8 is a side elevation of a third nonwoven fabric made in accordance with the present invention;

Fig. 9 is a perspective view of a fourth nonwoven fabric made in accordance with the present invention;

Fig. 10 is a perspective view of a further nonwoven fabric made in accordance with the present invention.

Referring to Fig. 1 an apparatus 10 for making a nonwoven fabric in accordance with the present invention comprises a plurality of feed heads 13 mounted in such a manner as to facilitate translational movement in both the X and Y directions as well as vertically in the Z direction. Each feed head comprises up to 350 dispensing nozzles. In the Y direction the feed heads must be capable

of sufficient travel such that material for making the fabric may be deposited from at least one of the nozzles of a feed head at any position in the Y-axis between the edges of the fabric being manufactured on the belt. Ideally the limitation of travel of adjacent feed heads 13 is such that the areas over which adjacent nozzles 13 may pass overlap. Vertical movement in the Z-direction of up to about 5mm is required.

Each feed head 13 is connected via a flexible pipe 15 to a reservoir (not shown) of heated fluid polymeric material that is normally solid in ambient conditions and which melts when sufficiently heated. The viscosity of the molten material is ideally in the range from 80-300 Centipoise measured at room temperature (20° C). An ionic resin may be used, such as SURLYN (Trade Mark) as marketed by Du Pont. In accordance with the techniques described in US 5501824 the flow of polymeric material via a valve at the end of the nozzle 13 is controlled by a computer. That computer is connected to a CAD system on which is located a representation of the section of the nonwoven fabric being reproduced in 3D form by the apparatus.

In use the section or panel of nonwoven fabric being reproduced is formed on an endless belt 14 tensioned between two rollers. The belt would, generally speaking, comprise a fabric, optionally coated with a non-stick coating such as PTFE.

A representation of the panel is provided on the CAD system. The control computer effectively slices the CAD representation into a plurality of virtual layer representations, which are together known as a building representation. The control computer uses the data on the CAD system to

reproduce stepwise layer by layer of the panel of the nonwoven fabric on the belt 14 by appropriate application of the molten polymeric material. As drops of polymeric material are deposited onto the belt, or as the process progresses, onto previously solidified material, there is a rapid heat loss and the drops solidify. Accurate location and flow of the polymeric material is achieved by a combination of controlling flow of the polymer through the nozzles 13 via a valve, movement of the nozzles 13 in the X, Y and Z directions. In the formation of a single section or panel of the fabric the method used is much the same as that described in US 5501824, except in that no additional exterior support is generally required to manufacture fabrics of the invention in that they are essentially flat structures, and a moveable belt 14 is used in place of a platform. Furthermore, strength-providing yarns are generally included in the fabric.

Once the panel is constructed in accordance with the representation on the CAD system, the belt will then advance in a controlled manner to the position to which additional material is to be added to form the next panel or panels.

After a layer of panels has been formed it may be advantageous to fill in any hollow areas in that layer with a second material in order to provide support to the next layer. This is a so-called "temporary lay down phase". This second material can be removed once manufacture is complete, for example by washing or melting when the second material has a lower melting point than the material from which the fabric is made. In order to dispense this second material certain nozzles of the dispensing heads would be connected via a flexible pipe to a reservoir of such material and not to the fabric-forming material.

Referring to Figs. 2 and 3 part of a nonwoven fabric 20, in accordance with the invention, is illustrated. This comprises a fine planar upper grid 21 secured to the tips of a series of parallel cross-machine direction lands 22, which, in this embodiment, are triangular in section. The flat bases of these triangular lands 22 are secured to an array of parallel machine direction lands 23 which are square in cross section. The width of the paper contacting lands in the grid 21 is typically in the order of 0.1mm. The depth of this layer is typically about 0.1-0.2mm. The dimensions of the apertures defined by the lands are preferably at least 100 microns by 100 microns, though the hole shapes need not be rectangular.

It is noted that the position of the CMD lands 22 relative to the paper formation grid 21 may be varied. For example, two triangular lands 22 might cover or straddle the holes. Many variations are possible in the interests of providing optimum dewatering efficiency and performance.

Videomicroscope at magnification of 55X shows that hemispheres of polymer; i.e. micro-globules are produced on the surface of the lands in that the lands are built up from globules of polymer. These micro-globules help provide for good sheet release without resulting in marking of the paper formed on the surface of the structure.

In some circumstances it may be desirable to provide a non-planar support surface at a macroscopic level. For example, this may be useful in providing sheet release with difficult pulp mixtures. Such a surface could be conferred upon the fabric by means of a non-planar receiving belt. This could be used to provide an, at least partially, undulating fabric surface of the type described in US 5,837,142.

Referring to Fig. 4 a monofilament yarn 24 of maximum diameter 0.2mm is encapsulated in each of the machine direction lands 23 below the fabric supporting grid 21 so as to provide strength in the running direction of the fabrics when in use. These monofilament yarns could be pre-assembled in spiral fashion during manufacture. The laying down of polymeric material would take account of the very slight sideways movement of the yarns. An electronic follower could be used to establish an exact reference point before the onset of printing each panel.

In Fig. 4 the sequence of fabric build (a) to (c), at the roll side of the fabric, shows how a semi-circle is created to allow yarn to be introduced at (a). Thereafter in (b) and then (c) the jet printing of material builds up around the yarn to eventually fully encapsulate it.

The strength providing yarns in the machine direction need not be monofilaments. For example, fine multifilament yarns could be used (e.g. dtex 500). The yarns may, for example, be made of steel, polyester, polyamide, polyolefin, PPS, PEEK, para-aramid or from inorganic material, e.g. glass or basalt. Bonding to the polymeric surface may be enhanced by suitable surface treatments such as tie-coats or surface activation such as plasma treatment.

As an alternative or in addition to incorporating monofilament yarns in the machine direction lands, a nonwoven fabric of the invention may be secured on its underside, to a conventional fabric such as a woven fabric or possibly to a further nonwoven fabric or knitted fabric. The fabric of the invention can also be secured at its topside to a fine woven forming fabric to yield specific formation properties as desired or to nonwoven fibrous batts.

The fabric would ideally be built up in endless form to avoid seaming problems as are commonly encountered in the art when making seamed belts, particularly for use in papermaking. Such problems are more apparent for belts used at the wet end of the papermachine; i.e. forming fabrics. Here differential permeability between the seam and the rest of the belt can cause unacceptable marking of the paper sheet as formed in the seam area of the belt. Considerable time and effort and thus cost are involved in attempting to minimise these problems. Nevertheless it is feasible that seamed fabrics may be made in accordance with the present invention.

The fabric has particular application as a forming fabric in that it provides a fine support network for the paper furnish whilst at the same time allowing for controlled drainage, as aided by the orientation, number and cross-section of the created "yarns" or filaments within the fabric. The adoption of at least some filaments that are triangular (including substantially triangular), or other yarns having a good hydrodynamic shape, is valuable in this respect.

It will be appreciated that previous stereolithographic techniques have resulted in the formation of a non-durable temporary product of relatively small dimensions. The apparatus previously used to produce such products is not of sufficient scale to generate fabrics in accordance with the invention that might typically be 11m by 30m. The invention proposes to build up the fabric from a number of filaments extending in both the machine direction and cross machine direction. This is achieved using an array of multi-jet heads, which effectively print a series of panels in a row, ideally in the cross-machine direction. This is illustrated in Fig. 5. Here the heads are programmed by the computer to print

panels 25 with multiple tongue and groove combinations, alternative arrangements being shown in Figs. 5a and 5b. In Fig. 5b some tongues are chosen to be longer than others to enhance panel bonding. In both Figs. 5a and 5b the panels are made up stepwise by a series of layers Z_1-Z_5.

The growth of the fabric in the machine direction is achieved by forming a panel, or in the case of a multi-head manufacturing assembly a series of panels, onto the moveable belt 14.

With reference to Fig. 6 it is envisaged that the support belt for the growing foraminous polymer assembly could possibly advance continuously but slowly forwards, but generally speaking and preferably, the belt would be arrested in a static state whilst a full panel consisting of discrete layers $Z_1 - Z_4$ is built up. This intermittent movement of the belt provides for more accurate delivery of the polymeric material. Another benefit is that maintenance of the polymer feed heads can take place whilst the belt is in a static state without detriment to any partially manufactured belt on the machine. When the complete panel 25 (i) has been constructed the belt then advances for the commencement of the following panel 25 (ii). This process is repeated until the complete belt has been manufactured in both length and width directions.

Because of the accuracy of the micro control system of the process, incomplete panels, both in the machine direction and the cross machine direction can be built-up. The lack of completion makes for better integration with adjacent panels when they are started as the processing progresses.

In the running direction an incompleted step will be left at the rear of the panel previously built up. If, for the sake of example, a foraminous belt is derived

from four layers Z_1, Z_2, Z_3, Z_4, the complete panel will contain 100% of layers Z_1 and Z_2. However, layers Z_3 and Z_4 may either be the same or selected to be different. The incomplete areas, Z_3 and Z_4 are then filled in when the following panel is built up. The benefit of this split-level assembly is likely to be the derivation of a better-integrated fabric.

It can be seen that the laid-down area of all four layers is identical. Layers Z_4 and Z_3 are simply displaced in a forwards direction relative to Z_2 and Z_1. The overlap situation created aids inter panel bonding and contributes to better production uniformity.

In Fig. 7 in a further fabric 30 in accordance with the invention the tips 31 of the triangular cross-machine lands 32 have been, where they contact the grid 33 located thereupon, modified to create flat areas 34. These create a large contact area for bonding to the upper grid 33. The same procedure would be adopted for filaments generated with alternative end sections.

Referring to Fig. 8 a further embodiment 35 of the nonwoven fabric of the invention is illustrated. Here the triangular end section intermediate layer has been replaced with angled ribs 36. This may serve to better control drainage.

In the embodiment illustrated in Fig. 9 a sheet 37 comprising an array of perforations of random size and shape is used to support the paper web, although the overall integrated (or average) pore size over a given area ideally remains uniform. By providing randomised topographical perforation distribution in the x-y plane, regular patterns of apertures from the forming fabric, which are conventionally replicated as a negative in the paper product, are not so replicated.

Thus no regular pattern is perceptible, this so-called periodicity being considered to be undesirable in papermaking.

The fabric of Fig. 9 is made in a like manner to the other fabrics of the invention as previously described. It is relatively straightforward to build up a fabric in which a support sheet layer having a random distribution of holes is integral with regularly spaced lands located therebelow. A temporary lay down phase of wax or the like is used to fill the gaps between the lands below the intended location of the sheet and the sheet is built up over the lands and temporary filler material. This temporary material is removed, for example by washing or melting, after fabric manufacture is complete.

The embodiment of Fig. 10 is similar to that shown in Fig. 9 except that the cross-machine direction triangular lands 38 are curved so as to prevent them from encroaching upon the perforations in the paper pulp support layer 39 which is similar to that described with reference to Fig. 9.

It is to be understood that the above described embodiment is by way of illustration only. Many modifications and variations are possible.

FIG. 1

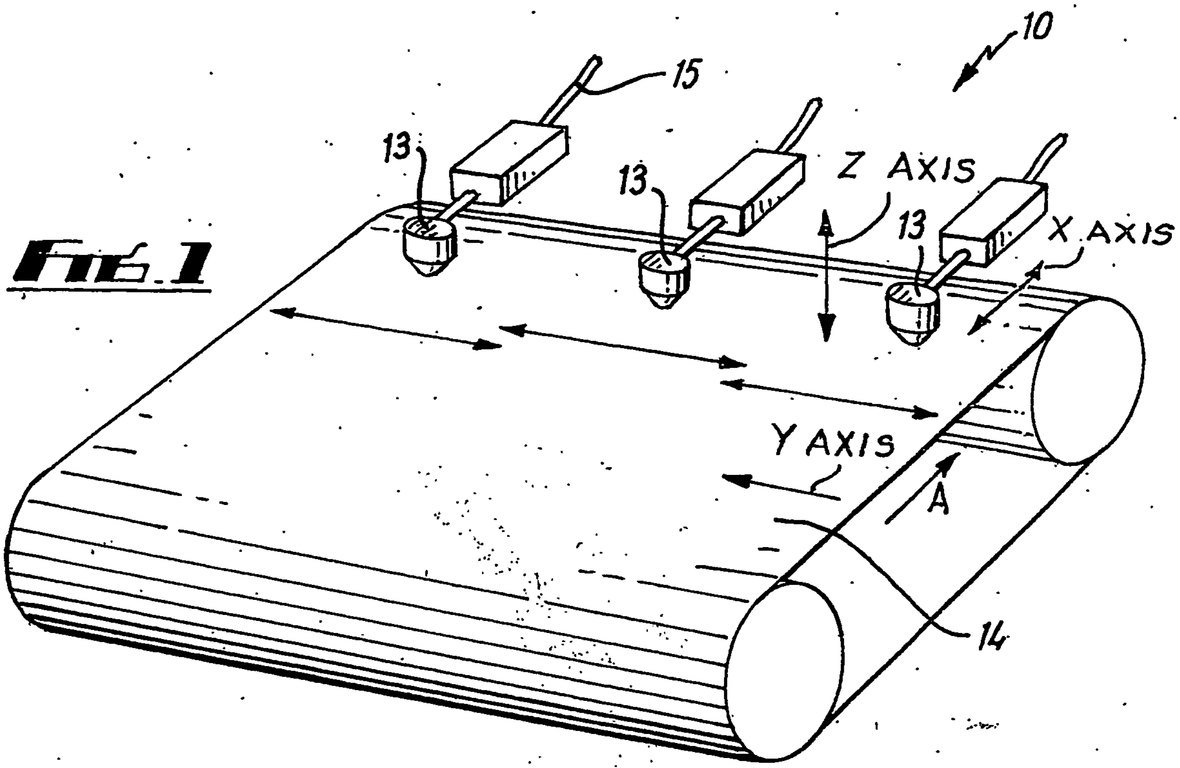
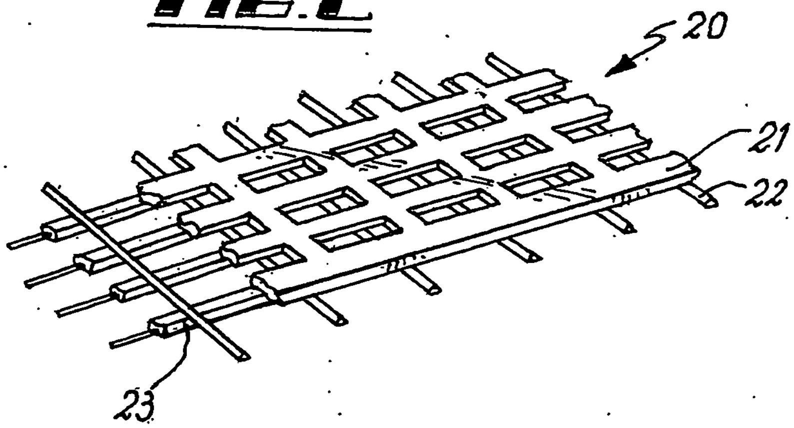


FIG. 2



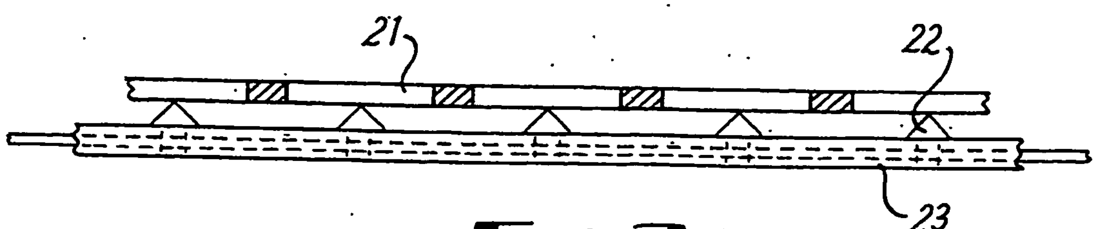


FIG. 3

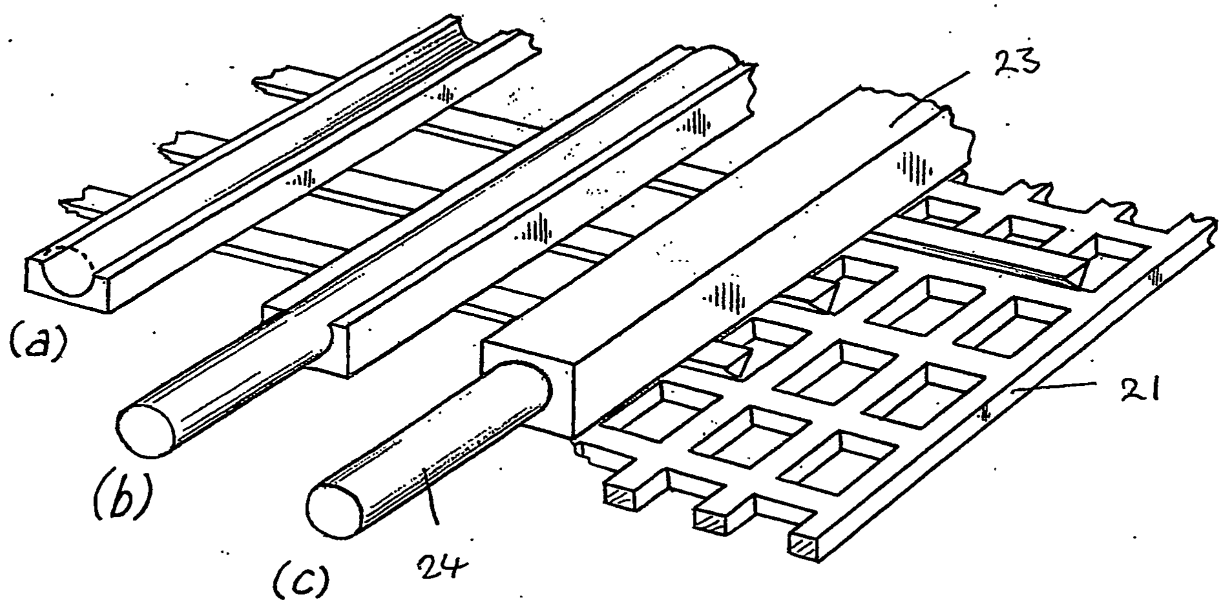


FIG. 4

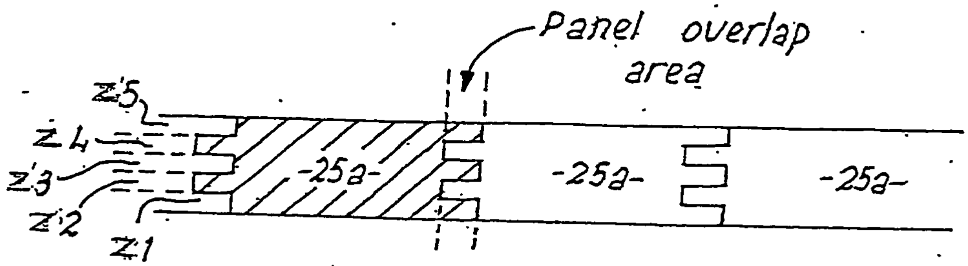


FIG.5a

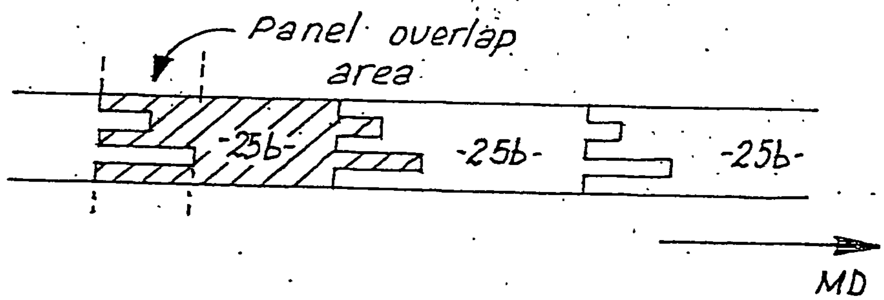


FIG.5b

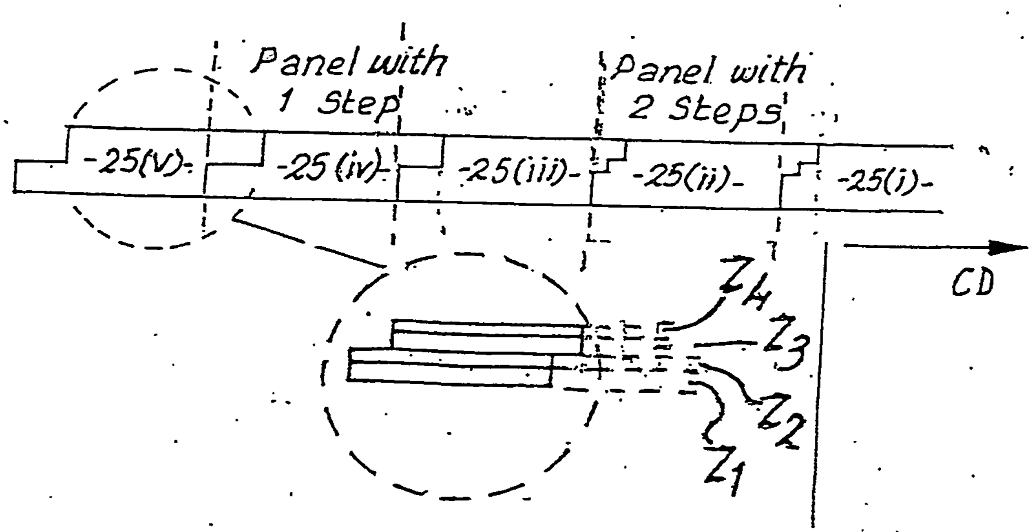


FIG.6

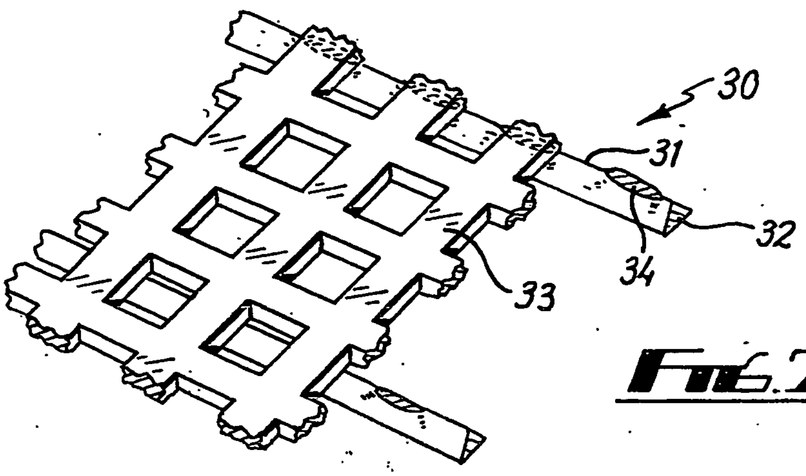


FIG. 7

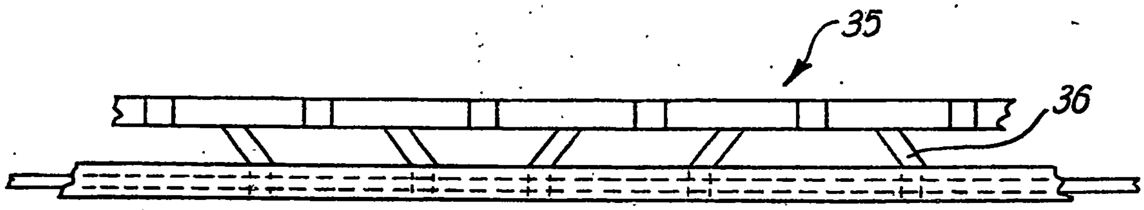


FIG. 8

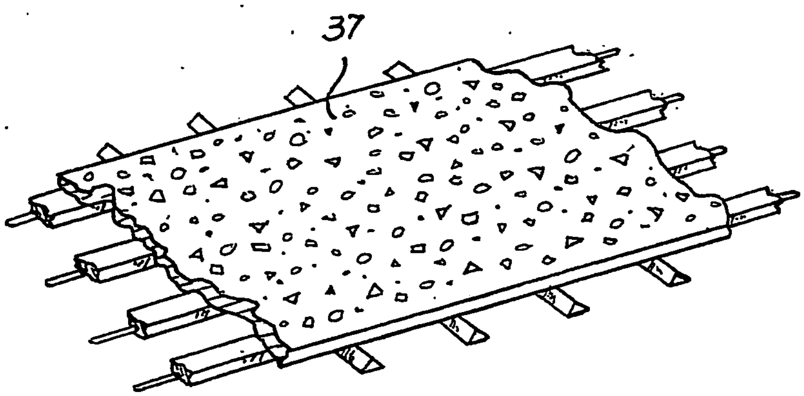


FIG. 9

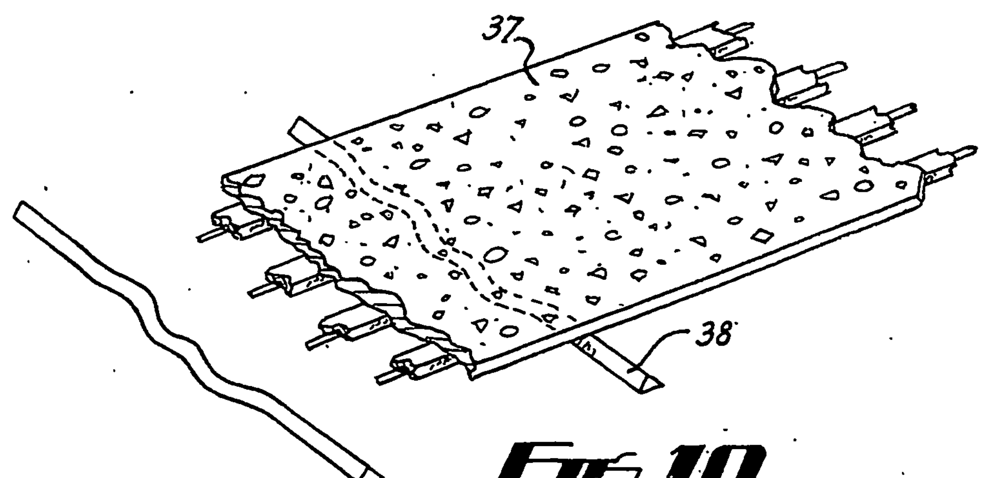


FIG. 10